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4. The heart, at least the heart of the frog, has two distinct sets of nervous fibres, those of the pneumogastric and those from the ganglion-cells, which are both distributed to the muscles. The vagus therefore acts directly on the muscular fibres of the organ, and the well-known experiment of Weber can scarcely be explained through a supposed action of the vagus on the ganglia. On the other hand, the ganglia and their fibres are also motorial organs of the heart, and alone act when it is separated from the body.

May 8, 1862.

Major-General SABINE, President, in the Chair.

Heinrich Wilhelm Dove, of Berlin, elected a Foreign Member in 1850, and Henri Victor Regnault, of Paris, elected a Foreign Member in 1852, were admitted into the Society.

The following communication was read :—

“Appendix to the Account of the Earthquake-Wave Experiments made at Holyhead.” By ROBERT MALLET, Esq., C.E., F.R.S. Received March 27, 1862.

(Abstract.)

This communication contributes the sequel of the author’s “Report on Earthquake-Wave Experiments” (made at Holyhead), as published in part 3 of the ‘Philosophical Transactions’ for 1861. At the conclusion of that paper the author expressed his hope of being able soon to lay before the Royal Society some experiments for the determination of the modulus of elasticity of perfectly solid portions of both the slate and the quartz rock formation through which his wave-transit experiments had been made at Holyhead, with a view to throw light upon the relations between the theoretic velocity of transmission (if the rocks were all solid and homogeneous) and the actual velocity as determined by experiment.

He has now determined the elastic modulus for both rocks, and for each rock in two directions, viz. parallel to and transverse to its lamination; and he has extended his determinations to specimens of

each rock of maximum and of minimum compactness and hardness, so that the series of experiments upon the compressibility of these rocks (from which the modulus is derived) assumes the following divarication, viz. :—

Slate rock ..	Hardest .	{ B. Parallel to laminæ, Table 2.
		{ A. Transverse to laminæ, Table 1.
	Softest ..	{ F. Parallel to laminæ, Table 6.
		{ E. Transverse to laminæ, Table 5.
Quartz rock .	Hardest .	{ D. Parallel to laminæ, Table 4.
		{ C. Transverse to laminæ, Table 3.
	Softest ..	{ H. Parallel to laminæ, Table 8.
		{ G. Transverse to laminæ, Table 7.

Involving thus eight distinct series of experiments.

The compressions were conducted at the Royal Arsenal, Woolwich, by the aid of the excellent American machine belonging to the Royal Gun-factories, permission to use which was accorded to the author.

The specimens of rock submitted to pressure were all equal cubes of 0·707 inch on the edge, presenting thus a surface on each side of 0·5 square inch—a dimension presenting facilities for tabular reduction, &c.

The cubes were cut from the chosen rock specimens (selected with care as fairly representative) by means of the lapidary's wheel, and had opposite faces rigidly parallel and equal.

The pressures advanced by 1000 lbs. per square inch of surface, from zero up to the crushing point of the specimen ; and at each advance the actual compression of the column of rock was measured by instrumental arrangements that admitted of reading space to ·0005 of an inch. The results are given in Tables numbered 1 to 8, referred to above, and these are compared in two Tables numbered 9 and 10.

The following are the mean compressions for each 1000 lbs. per square inch :—

Slates.				Quartz.			
A.	B.	E.	F.	C.	D.	G.	H.
inches. ·000627	inches. ·0025000	inches. ·0039144	inches. ·0037000	inches. ·0007085	inches. ·0010947	inches. ·0014666	inches. ·0172666
up to 23,000 lbs.	up to 26,000 lbs.	up to 14,000 lbs.	up to 7000 lbs.	up to 35,000 lbs.	up to 19,000 lbs.	up to 12,000 lbs.	up to 6000 lbs.

Crushing usually took place at 1000 to 2000 lbs. additional pressures beyond the above limits, up to which the compressions were tolerably uniform.

The discussion of these Tables fully presents some interesting and novel results.

Generally the quartz rock is less compressible than the slate; the softest quartz, however, is much more compressible than the softest slate in a direction parallel to the lamination of both. In this direction also the hardest slate is more than double as compressible as the hardest quartz. Transverse to the lamination, however, both the hardest slate and quartz have nearly the same coefficient of compressibility, which is very small for both. In the latter direction also the *softest* slate and quartz have almost the same coefficient, but one about *four times* as great as for the *hardest* like rocks.

The author points out several conclusions of much interest deducible from these experiments as to the physical and geological conditions under which these rocks were formed and consolidated. The compression by natural forces has already been greatest in directions transverse to the lamination. The great compressibility in the opposite directions, or parallel to the lamination, appears to arise chiefly from the mass of the rock being made up of minute wedge-shaped mineral particles, deposited all with their largest dimensions on the plane of lamination, and so acting on each other like wedges.

Some curious circumstances in the mode of giving way of the rocks under pressure are shown by the author to be probably connected with their mass being formed of an aggregate of several simple minerals.

He points out the great differences in wave-transmissive power in directions transverse to and parallel to the lamination which these experiments disclose. The specific gravities of the several specimens of rock are then given, to enable the modulus of elasticity to be obtained in feet, and the general results of the experiments are comprised in the following Table (p. 87):—

The author then proceeds to apply these results to the comparison of the theoretic and actual transit-periods of the wave of impulse.

The general expression for elastic wave-propagation in a homogeneous medium may be expressed by an equation of the form

$$V = \sqrt{gL} = 8.024 \sqrt{L},$$

HOLYHEAD ROCK COMPRESSION.

General results reduced, modulus of cohesion and of elasticity, &c.—Slate and Quartz.

No.	Class of rock, and direction of pressure in relation to structure.	Coefficient of compression on unit surface for 1000 lbs.	Elastic limit for compression.	Crushing load on the unit of surface.	Modulus of cohesion (compression).	Modulus of elasticity.	Modulus of elasticity.	Coefficient of elasticity.
1	Slate <i>hardest</i> across lamination	·0006217	22,000	lbs. 24,000	feet. 20,014	lbs. 8,042,464	feet. 6,706,524	1·2432
2	Quartz <i>hardest</i> across lamination	·0007085	32,000	37,000	32,095	7,057,163	6,121,758	2·1830
3	Slate <i>hardest</i> parallel to lamination	·0025009	18,000	27,000	22,515	2,000,000	1,667,778	5·6241
4	Quartz <i>hardest</i> parallel to lamination	·0010947	17,000	20,000	17,349	4,567,461	3,962,013	1·8240
5	Slate <i>softest</i> across lamination	·0039144	12,000	15,000	12,586	1,277,335	1,071,769	4·8930
6	Quartz <i>softest</i> across lamination	·0014666	11,000	14,000	12,158	3,409,246	2,960,699	1·7108
7	Slate <i>softest</i> parallel to lamination	·0037000	6,000	9,000	7,552	1,351,351	1,133,874	2·7747
8	Quartz <i>softest</i> parallel to lamination	·0172666	7,000	8,000	6,948	289,576	251,477	11·6112
<i>Calculated Means.</i>								
9	Slate, mean for hard and soft across lamination	·0022680	17,000	19,500	16,311	2,204,585	1,844,069	3·6855
10	Quartz, mean for hard and soft across lamination	·0010875	16,500	25,500	22,132	4,597,701	3,990,455	2·3103
11	Slate, mean for hard and soft parallel to lamination	·0031000	12,000	18,000	15,056	1,612,903	1,349,145	4·6494
12	Quartz, mean for hard and soft parallel to lamination	·0091806	12,000	14,000	12,151	544,627	472,684	10·7100
<i>Calculated Means of Means.</i>								
13	Slate, hard and soft, mean for both directions (Nos. 9 and 11)	·0026840	14,500	18,750	15,684	1,862,880	1,566,541	4·1914
14	Quartz, hard and soft, mean for both directions (Nos. 10 and 12)	·0051340	16,750	19,750	17,141	973,899	845,252	8·4490
15	General mean for slate and quartz, hard and soft, and in both directions (Nos. 13 and 14)	·0039090	15,625	19,250	16,398	1,279,099	1,089,615	6·2697

where L is the modulus of elasticity in feet. Where, from want of homogeneity or shattering, &c., as found in nature, the experimental value of V differs from this, we may express it by the same form of equation,

$$V' = \alpha \sqrt{L},$$

the coefficient α having to $\sqrt{2g}$ the rate that the actual bears to the theoretic value of V .

He then determines the value of α for three of his mean experimental transit-velocities at Holyhead, and obtains as follows :—

Feet per side.

$$V' = 1089 \quad \alpha = 0.637$$

$$V' = 1352 \quad \alpha = 0.791$$

$$V' = 1220 \quad \alpha = 0.714$$

The actual velocity of wave-transmission in the slate and quartz rocks, taken together, was to the theoretic velocity due to their materials, if perfectly solid,

$$\alpha : \sqrt{2g}, \text{ or as } 1.00 : 8.89;$$

so that nearly eight-ninths of the full velocity of wave-transmission due to the solid material is lost by reason of the heterogeneity and discontinuity or shattering of the rocky mass as it is piled together in nature.

The author then shows that were the rocks *quite solid*, the velocity of wave-transmission would be—

Mean of slate and quartz transverse to lamination $V = 13,715$ feet per second.

Mean of slate and quartz parallel to lamination $V = 7659$ feet per second.

This difference is probably reversed *in nature* by reason of the greater discontinuity in the former direction. The author then shows that his results, which appear at first sight to conflict with those of an analogous character obtained by Helmholtz and others for wood, in the three principal directions of its section, are strictly in accordance and analogy with the results of these experimenters.

The author concludes by deducing some conclusions as to the bearing power, safe load, and proper direction as to lamination when exposed to pressure, of these rocks, of a practical character, and valuable to the civil engineer or architect.